AFRL-SA-WP-SR-2012-0007

BASE LEVEL GUIDE FOR THE OCCUPATIONAL EXPOSURE TO BERYLLIUM

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March 2012

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From – To)*
1 Mar 2012	Special Report	Feb – Mar 2012

4. TITLE AND SUBTITLE

Base Level Guide for the Occupational Exposure to Beryllium

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Timothy W. Batten

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USAF School of Aerospace Medicine
Occupational & Environmental Health
Risk Analysis Division/OEHR
2510 Fifth St.
Wright-Patterson AFB, OH 45433-7913

8. PERFORMING ORGANIZATION REPORT NUMBER

AFRL-SA-WP-SR-2012-0007

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution A: Approved for public release; distribution is unlimited. Case Number: 88ABW-2012-3222, 6 Jun 2012

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This base-level guide provides information on the most common sampling and analysis techniques used to determine the health risk of beryllium. The sampling and analytical challenges associated with measuring beryllium are greater than for most other metals; therefore, beryllium exposure must be managed at ultra-trace levels. This includes workplaces actively using beryllium and contaminated legacy areas where beryllium was used in the past. This guide is set up as a series of questions and answers to help bioenvironmental engineers and technicians quickly progress through the decision-making steps.

15. SUBJECT TERMS

Occupational exposure, beryllium, 7300, sampling, analysis

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Capt Timothy W. Batten
U	U	U	SAR	14	19b. TELEPHONE NUMBER *(include area code)*

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1.0 INTRODUCTION

This base-level guide provides information on the most common sampling and analysis techniques used to determine the health risk of beryllium. The sampling and analytical challenges associated with measuring beryllium are greater than for most other metals; therefore, beryllium exposure must be managed at ultra-trace levels. This includes workplaces actively using beryllium and contaminated legacy areas where beryllium was used in the past. This guide is set up as a series of questions and answers to help bioenvironmental engineers and technicians quickly progress through the decision-making steps. If you want information on more advanced methods, contact the Environmental, Safety, and Occupational Health (ESOH) Service Center at DSN 798-3764, 1-888-232-ESOH (3764), or esoh.service.center@wpafb.af.mil.

2.0 WHAT OCCUPATIONAL AND ENVIRONMENTAL EXPOSURE LIMIT (OEEL) SHOULD I USE?

The Occupational Health and Safety Administration (OSHA), the United States Air Force (USAF) Surgeon General's Office, and the American Conference of Industrial Hygienists (ACGIH) each have promulgated OEELs for beryllium for which the Bioenvironmental Engineering (BE) community needs to be concerned:

Group	Limit	OEEL ($\mu g/m^3$)	TWA
OSHA	PEL	2.0	8-h (Ref 1)
USAF	AL	0.2	Set at 1/10 of OSHA PEL[a]
ACGIH	TLV	0.05	Using only inhalable fraction (Ref 2)

Note: TWA = time-weighted average; PEL = permissible exposure limit; AL = action level; TLV = threshold limit value

[a]Department of the Air Force, Office of the Surgeon General, "Implementation Guidance for AF Medical Management of Workers Exposed to Beryllium" [Memorandum], 18 Nov 2010.

Additionally, there are two different sample techniques used in the above standards. The OSHA PEL and USAF AL are based on total particulate matter using a closed-face 37-mm gravimetric cassette, while the ACGIH standard is based upon the inhalable fraction technique. Studies have shown that the inhalable fraction method is a more efficient sampling method for capturing aerosol than the traditional closed-face 37-mm cassette techniques (Ref 3). Therefore, the USAF School of Aerospace Medicine (USAFSAM) suggests for most circumstances to first sample using the inhalable fraction technique (discussed later in this guide) for comparison to the **0.05 $\mu g/m^3$** ACGIH TLV. The sample results will then fall into one of three profiles: acceptable, unacceptable or uncertain (Ref 4).

2.1 **Acceptable Exposure** (Ref 4)

Since the inhalable fraction method is the most efficient technique and the ACGIH TLV of **0.05 $\mu g/m^3$** is the most stringent of the standards, results below this limit simultaneously satisfy all three OEELs. Multiple samples over time may be needed to adequately characterize the hazard based on a comprehensive exposure assessment strategy.

2.2 Unacceptable Exposure (Ref 4)

If the inhalable fraction result is above the USAF AL of **0.2 µg/m^3** or even worse the OSHA PEL of **2.0 µg/m^3**, then the exposure profile is uncontrolled unless additional control efforts are instituted following the control hierarchy of engineering, substitution, administrative, and personal protective equipment.

2.3 Uncertain Exposure (Ref 4)

Should the total particulate sample fall between the ACGIH level of **0.05 µg/m^3** and the USAF AL of **0.2 µg/m^3**, then no definitive conclusion can be made regarding either OEEL. This outcome describes neither a process that is controlled nor clearly requiring controls. Additional hazard characterization will be required, likely using side-by-side sampling of both the total and inhalable sampling techniques. Exposure profiles that fall in this gray area are extremely difficult to characterize and may require consultation from the Occupational and Environmental Health Department of USAFSAM (USAFSAM/OE) or may rely heavily on the professional judgment of the local BE. In either case, assessing a borderline exposure profile goes beyond the scope of this guide.

3.0 WHAT TYPE OF AIR SAMPLING DEVICE SHOULD I USE?

USAFSAM suggests starting with the most efficient method for collecting aerosolized particulates by using an inhalable particulate sampler, such as the SKC Institute of Occupational Medicine (IOM) inhalable sampler or the Button inhalable sampler. Sampling for inhalable particulate matter is a better application from a toxicity standpoint than the traditional "total" dust sampling methods since inhalable particulate sampling targets a size range that is more inclusive of all biologically relevant particles. However, if you want a definitive comparison of your results to the OSHA PEL, or the USAF AL, use the "total" particulate matter technique with a standard 37-mm cassette as outlined in the National Institute for Occupational Safety and Health (NIOSH) Method 7300.

4.0 IF I WANT TO COMPARE RESULTS TO THE NEW ACGIH TLV, HOW DO I MEASURE THE INHALABLE FRACTION?

The traditional 37-mm cassettes for "total" particulate matter do not satisfactorily capture the inhalable fraction. According to ACGIH, *inhalable particulate matter* is matter that is deposited anywhere in the respiratory tract and follows the collection efficiency shown by Figure 1.

The IOM sampler and the SKC Button inhalable sampler (Figure 2) are considered to have good accuracy and precision with respect to the ACGIH inhalable fraction curve. The IOM has the best fit with the inhalable curve under most circumstances. In contrast, the Button sampler has a lower sensitivity to high wind velocities (e.g., ≥ 2 m/s) and changes in wind direction. Also, the Button sampler does not allow very large particles (> 150 µm) to reach the filter. For abrasive blasting operations, the Button sampler will better protect the filter from tearing. The successful use of the Button sampler during USAF operations has been described in a number of peer-reviewed journal articles (Ref 5).

The manufacturer's instructions are available at the following websites:

IOM: http://www.skcinc.com/instructions/37372.pdf
Button: http://www.skcinc.com/instructions/3780.pdf

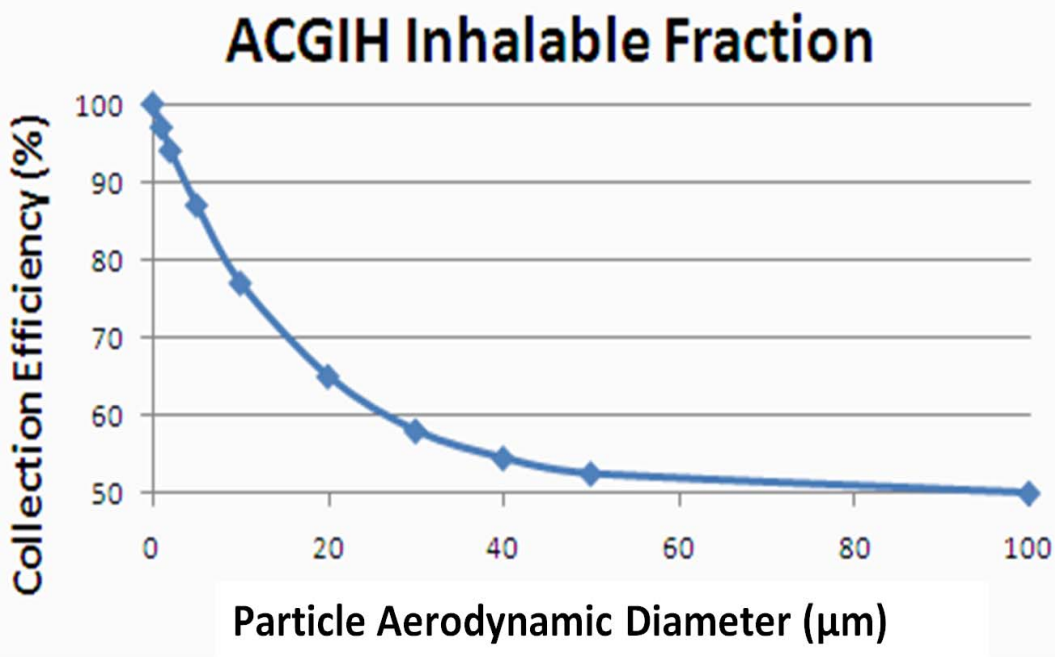

Figure 1. ACGIH's Inhalable Particulate Matter Collection Efficiency

Figure 2. IOM Inhalable Sampler and SKC Button Inhalable Sampler

5.0 HOW LONG SHOULD I SAMPLE?

Beyond the duration of the operation, the minimum sampling time can be calculated from the laboratory's reporting limit (RL), sampling flow rate, and the desired fraction of the OEEL. The duration of sampling should be long enough that when a nondetectable concentration is obtained, that concentration falls well below the desired OEEL of concern. As an example:

$$Minimum\ Sampling\ Time = \frac{RL}{OEEL \times (desired\ fraction) \times (flow\ rate)} \quad (1)$$

When analyzing for beryllium specifically, the most sensitive analytical method (expressed as RL above) will be used by USAFSAM/OE chemistry laboratory whether in-house or by contract lab. The sensitivity of the lab's analytical method allows for a shorter required sampling duration. When the exact value of the reporting limit is critical, USAFSAM recommends contacting the USAFSAM/OE chemistry laboratory to verify the current reporting limit before sampling. The USAFSAM/OE chemistry laboratory can be reached at USAFSAM/OEHTA_analytical@WPAFB.AF.MIL or DSN 798-2523.

To ensure the most sensitive analytical method is performed on beryllium samples, simply write on the sample request form "**BE analysis, NIOSH Method 7300 by ICP-MS.**" Currently, the USAFSAM/OE chemistry laboratory sends all samples requiring inductively coupled plasma mass spectrometry (ICP-MS) to a contract lab. The contract's lab RL by ICP-MS is currently 0.005 µg. Both USAFSAM and contract laboratory reporting limits are expected to change in the near future, as capabilities of the USAFSAM/OE chemistry laboratory improve.

As an example, the minimum sampling for comparison to the USAF AL of **0.2 µg/m^3** (or 0.0002 mg/m^3) and analysis by ICP-MS is shown below. The equation will provide all concentration values above **0.02 µg/m^3** (i.e., 1/10 of the AL OEEL) that are measurable. Note that changes in desired flow rate (1-4 L/min), the desired confidence level below the OEEL, or changes in the lab's RL will generate different minimum sampling times than the one used in this example for illustrative purposes only.

$$Minimum\ Sampling\ Time = \frac{(0.005\ \mu g) \times \left(\frac{1\ mg}{1000\ \mu g}\right) \times \left(\frac{1000\ L}{1\ m^3}\right)}{\left(0.0002\ \frac{mg}{m^3}\right) \times \left(\frac{1}{10}\right) \times \left(3\frac{L}{min}\right)} \quad (2)$$

Minimum Sampling Time = 83 min

To avoid underestimating actual exposures, USAFSAM recommends sampling both during the process and other activities thereafter. If ultrafine beryllium particles are generated during an operation, the dust might remain suspended long after the operation stops. The air may not be still enough for the dust to completely settle. The activities of the employees may resuspend dust that has settled on clothing articles. Dust can also be resuspended when workers pass by or walk over dusty surfaces, such as the factory floor, and when they perform any inappropriate cleanup operations such as dry sweeping or using a non-HEPA vacuum.

6.0 HOW MANY "BLANK" SAMPLES SHOULD I SEND TO THE LABORATORY FOR ANALYSIS?

NIOSH Method 7300 recommends 2 to 10 field blanks per set. Similarly, USAFSAM/OE recommends sending multiple "blank" filters and/or wipes to the laboratory for each sampling event. Chapter D of the NIOSH *Manual of Analytical Methods* recommends sending two field blanks for every 10 samples with a maximum of 10 field blanks for each sample set. The analysis results from multiple "blank" filters or wipes will provide an estimate of the range of contamination on the personal or area samples. Beryllium contamination (although rare) has been found on "blank" media in variable amounts in the past.

7.0 HOW DO I SEND THE MEDIA FROM THE IOM INHALABLE SAMPLER TO THE LABORATORY?

As described in the SKC operating instruction for the IOM, after sampling, remove the cassette from the sampler and place the cover on the cassette. The loaded filter in the cassette without the IOM body can be protected properly in the transport clip and cover. Send the cassette in the clip to the laboratory.

8.0 HOW DO I SEND THE MEDIA FROM THE BUTTON INHALABLE SAMPLER TO THE LABORATORY?

The SKC operating instruction for the Button sampler states to use forceps to remove the filter from the sampler. To minimize the possibility of sample loss, USAFSAM/OE recommends modifying the SKC operating instructions and NOT removing the filter. The entire Button sampler may be sent to the laboratory with the cap over the inlet screen and the plug over the outlet. USAFSAM/OE will send the cleaned Button sampler back to you.

9.0 SHOULD ALL FORMS OF BERYLLIUM BE ANALYZED IN THE SAME WAY?

With the exception of beryllium oxide (BeO), all other forms of beryllium and beryllium alloys can be analyzed interchangeably. For high-fired BeO ceramic samples, USAFSAM/OE recommends that an aggressive digestion procedure using sulfuric acid in conjunction with analysis by ICP-MS be used. Indicate on the laboratory sample request form "BeO."

10.0 WHERE CAN I GO FOR THE LATEST INFORMATION CONCERNING BERYLLIUM IDENTIFICATION, ASSESSMENT, AND CONTROL?

Updates to this document as well as additional documentation on beryllium can be found at the Air Force Knowledge Exchange Website in the beryllium folder located at the link below (available to those with access):

https://kx.afms.mil/kxweb/dotmil/kjFolderSearch.do?folder=Beryllium&queryText=healthprogramsBeryllium&functionalArea=ESOH

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LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AL	action level
BE	bioenvironmental engineering
BeO	beryllium oxide
ESOH	environmental, safety, and occupational health
ICP-MS	inductively coupled plasma mass spectrometry
IOM	Institute of Occupational Medicine
NIOSH	National Institute for Occupational Safety and Health
OE	occupational and environmental health
OEEL	occupational and environmental exposure limit
OSHA	Occupational Safety and Health Administration
PEL	permissible exposure limit
RL	reporting limit
TLV	threshold limit value
TWA	time-weighted average
USAF	United States Air Force
USAFSAM	United States Air Force School of Aerospace Medicine